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Bullets Behaviour in Ballistic Simulants

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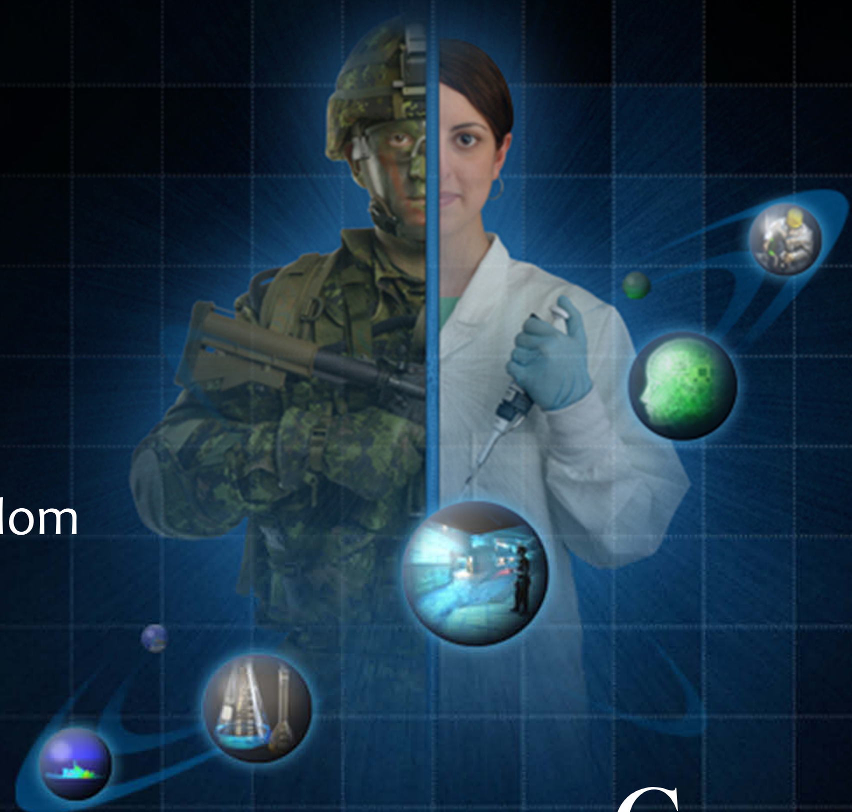

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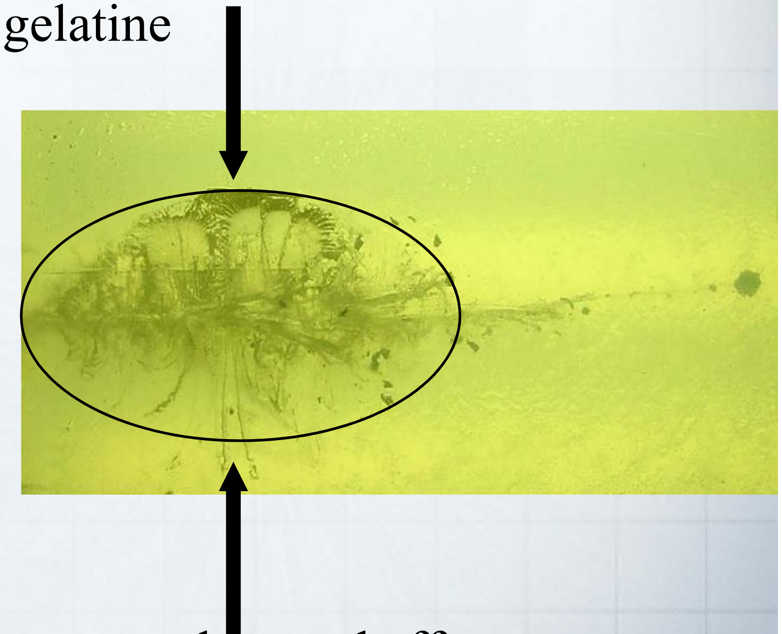
Goal

- Create a FE model capable of predicting the effect on the gelatin when stuck by different projectiles
- Perform a parametric study on the effect of calibre on wound track

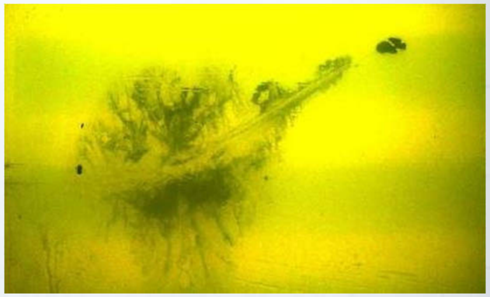
- The FEM needs to account for damage in the gelatine
  - Velocity decay
  - Dynamic cavitation
  - Permanent cavitation
  - Final penetration depth
- And projectile fragmentations



- Increases *Physical Understanding* of impact events and wound effects

Modelling of Terminal Ballistic Events

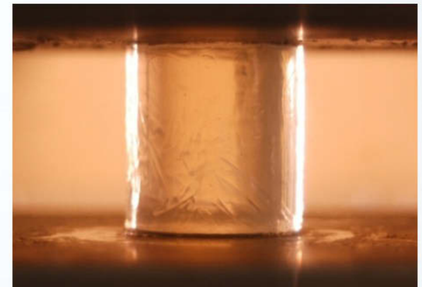
- Terminal ballistics events include
  - Impact, shock and blast loading on targets
  - Blast, lethal and blunt impact on human and animals
  - Penetration and perforation of targets
  - Behind armour effects

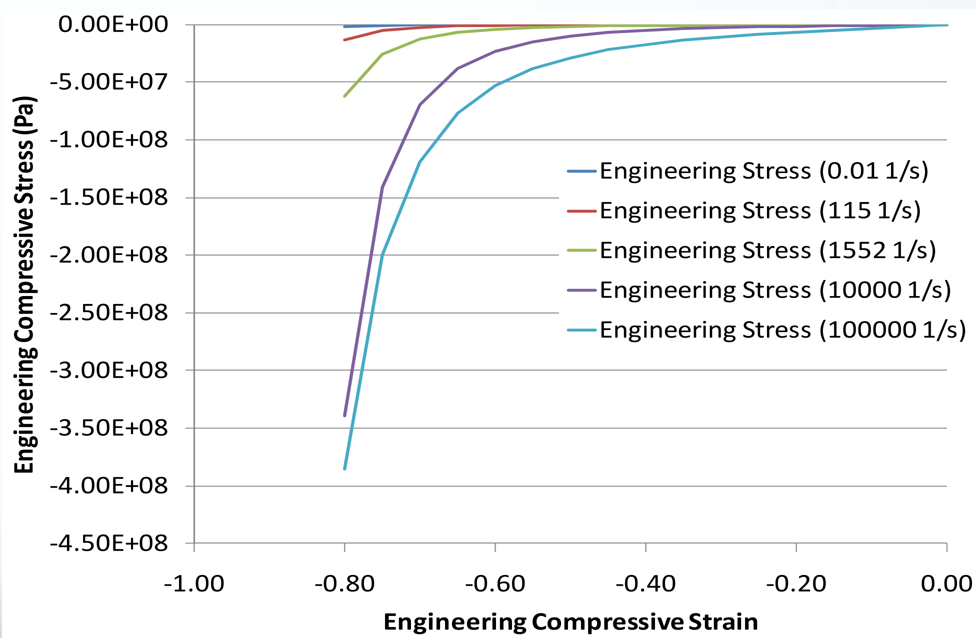


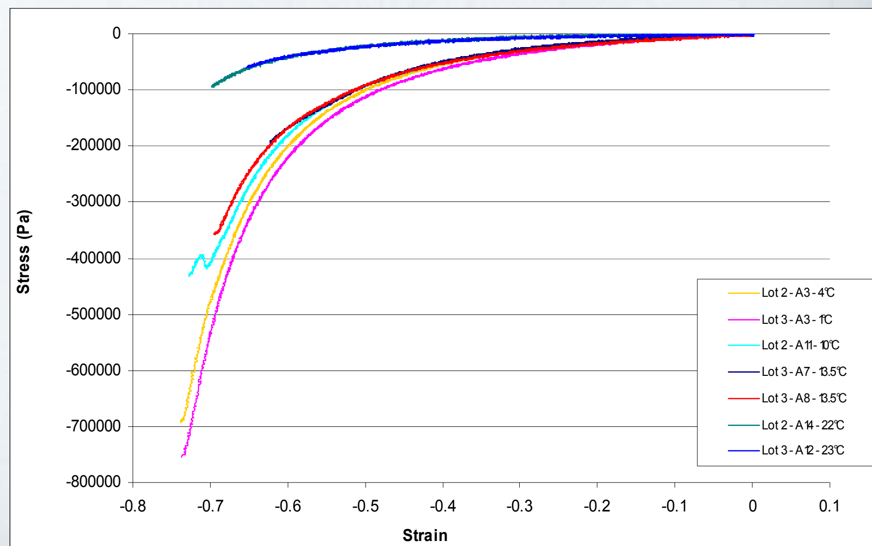
- Hydrocodes are used to model numerically terminal ballistic events
  - Finite element code used for analyzing response of targets under static or dynamic loading conditions

Constitutive Model for 10 % Gelatin

- The mechanical behaviour of ballistic gelatin is a typical <u>hyperelastic</u>
- Under SHPB tests, samples typically fail through the initiation of radial cracks
- Temperature has an effect
- Increasing stiffness with increasing strain rate



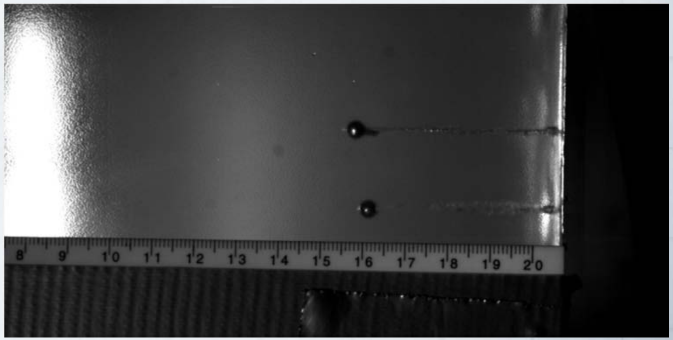




Temperature effect on quasi-static response of 10%, 4 ^{0}C ballistic gelatin at 0.01s^{-1}

Constitutive Model Implementation

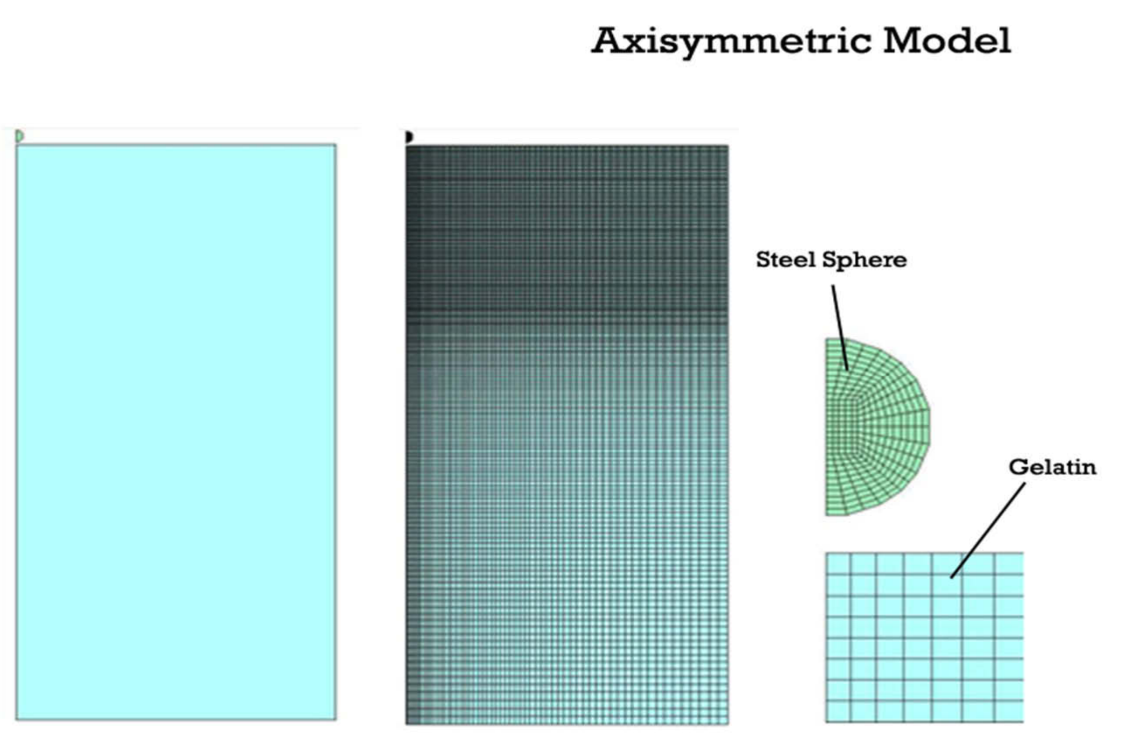
- Collect materials information at high strain rate
  - Compressive/tensile data
  - Penetration and wave speed
- Constitutive models
  - A traditional hyperelastic model was used but:
    - was insufficient for the intermediate and high strain rate
  - A rate-dependant hyperelastic constitutive model was used
    - Required tensile data
    - Sensitivity study demonstrated that the impact response was not significant dependant on the tensile response

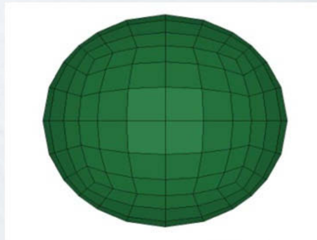


BB sphere

Steel Sphere (BB) Impact Model

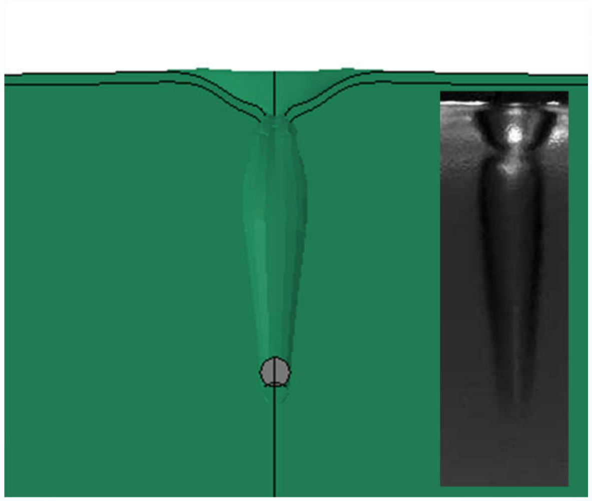
- The BB impact was used as a baseline to develop the material model and any associated failure criteria
- The nominal diameter was: 4.5mm (BB-type)
- Lagrangian formulation was used



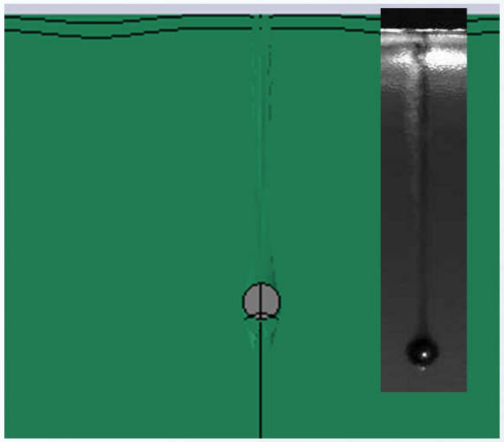


BB Steel Sphere

- The resulting temporary and permanent cavities are in reasonable agreement with typical gelatin response
- The permanent cavity is on the order of the projectile diameter, in agreement with Fackler
- The over estimation of the permanent cavity is due to *element erosion*



Temporary cavity

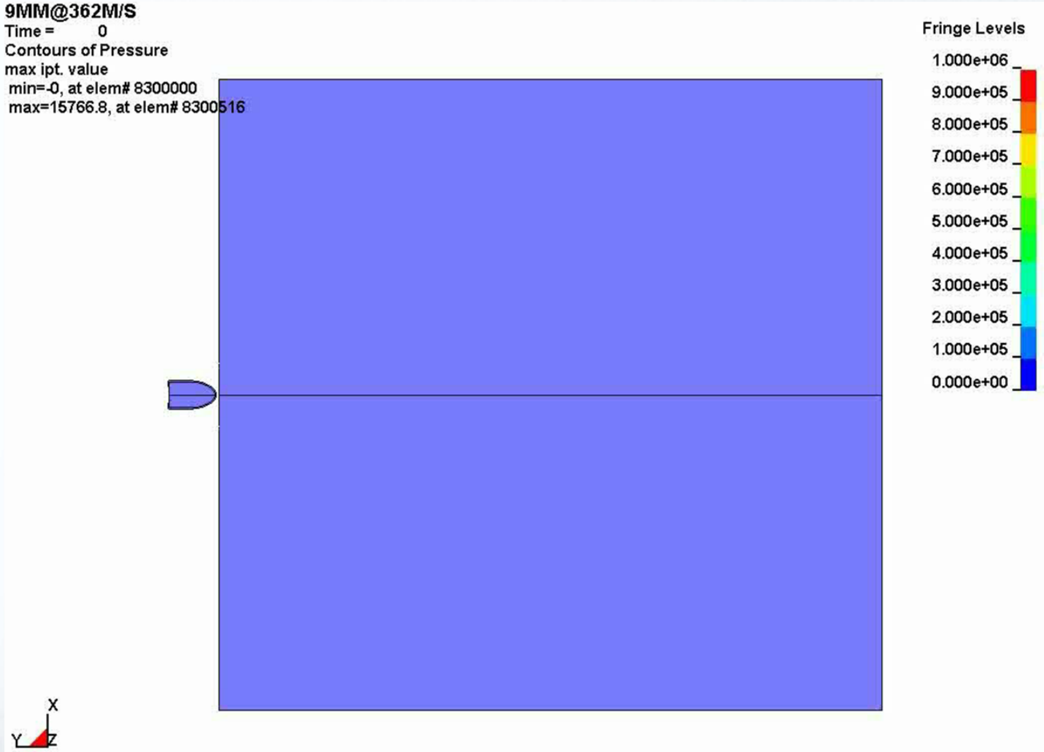


Permanent cavity

Velocity (m/s)	Target Penetration (mm)	Predicted Penetration (mm)
60	25.2	28.5
90	43.6	45.2
120	61.9	58.2

9mm Ball

- Results for a 2D 9mm NATO Ball model
  - Projectile does not deform and begins to tumble after approximately 150 mm penetration (6po)
  - Initial temporary cavity is approximately 2x the projectile diameter
  - 2D axi-symmetric analysis was in agreement with the experimental data



5.56mm bullet, high velocity

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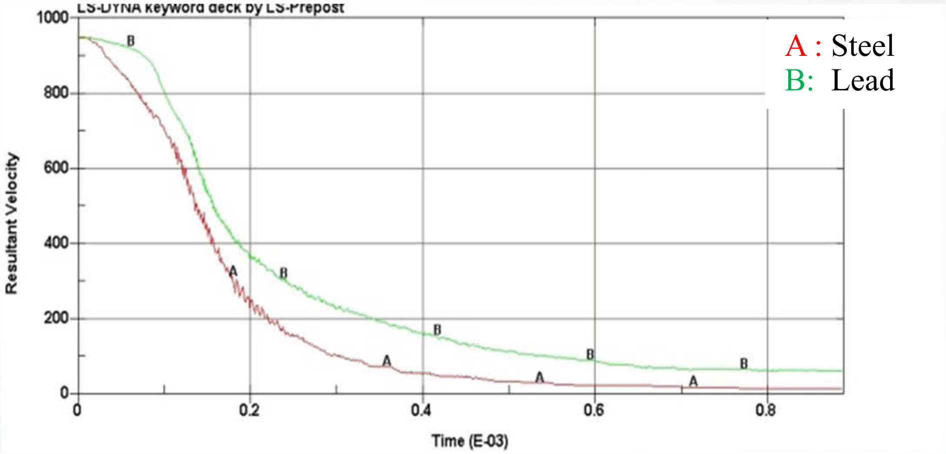
- Results for 5.56mm
  - Projectile does fragment and began deforming at 3po DP
  - The steel core fragment and detached from the projectile
  - The steel core was stopped at approximately 6po DP, while the lead completely penetrated the gelatine

t=0ms



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5.56 mm vs. 6.67 mm

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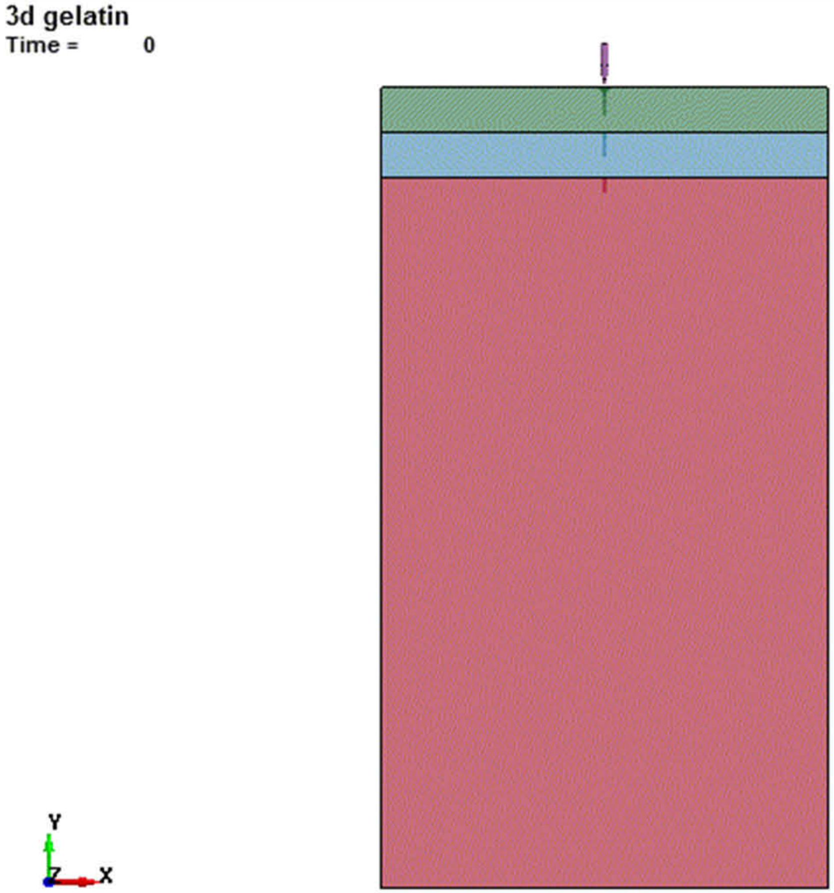
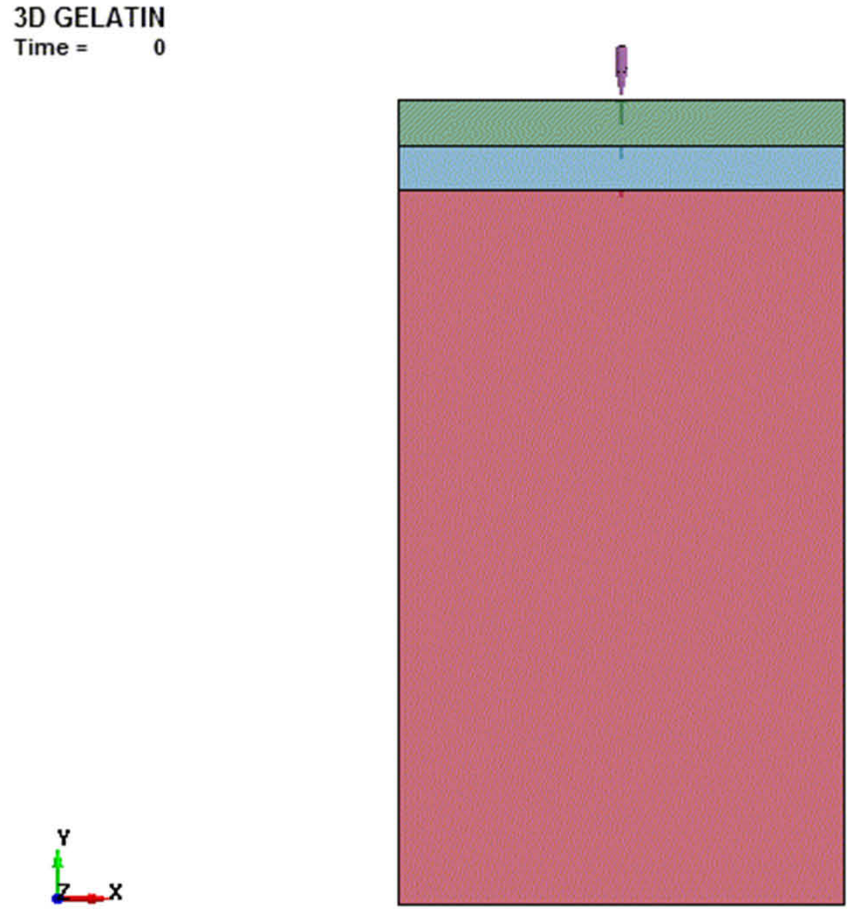
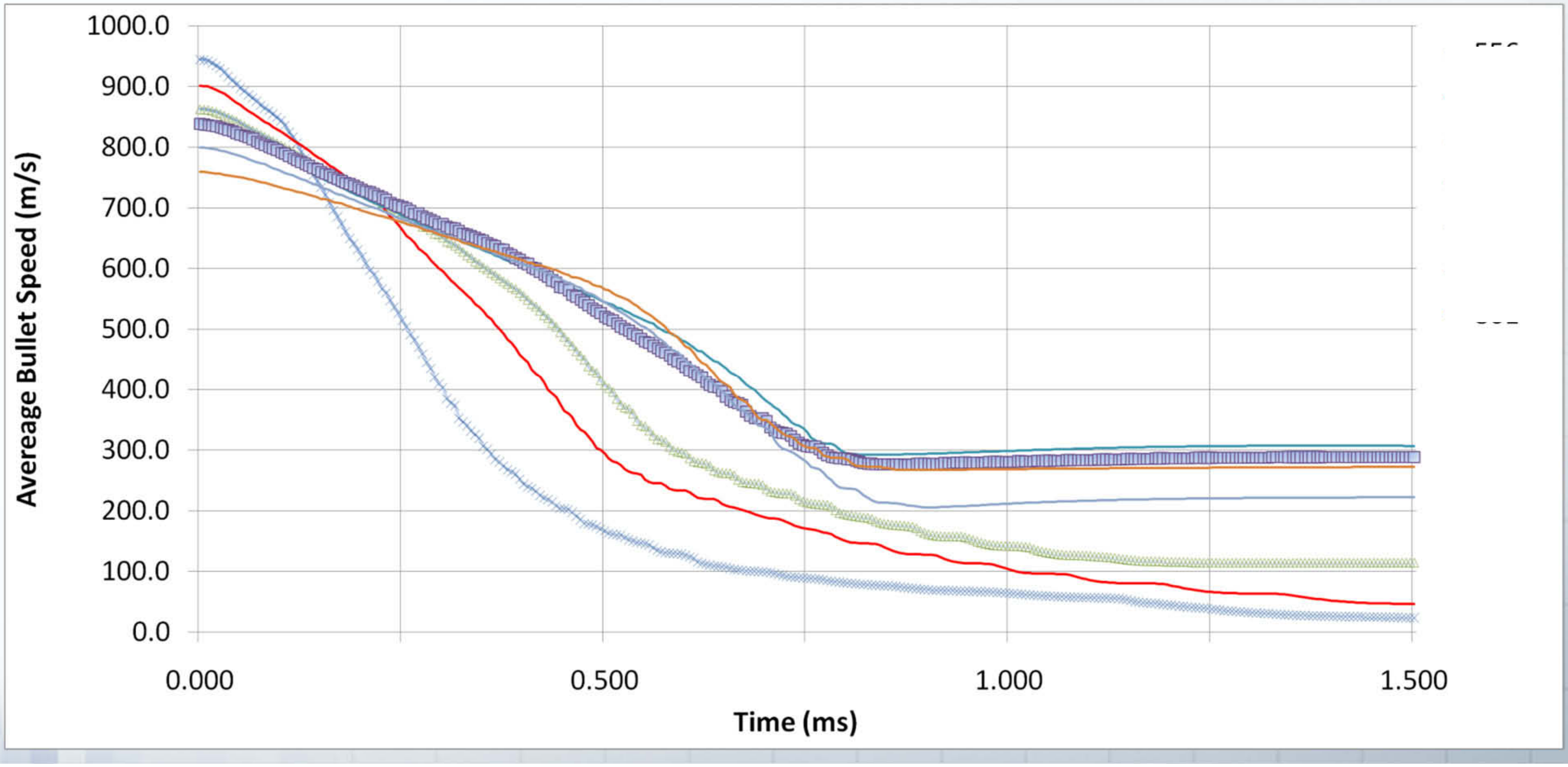




Average Bullet Speed

- Only 5.56 mm releases all its E.K. on the block
- 5.56mm decelerate quickly, has small neck length and fragment early
- 6.67 mm exits with low velocity and releases most of its initial E.K.
- Calibers from 7.62 mm and up behave in the same way



Conclusion

- In general:
  - Numerical modelling plays an important role in the study of terminal effects of small arms
  - Better understanding of the phenomena that are difficult to examine using experimental methods
  - Optimization of the number of experimental trials and savings of time and money
  - Fast trade up analysis for bullet design

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